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Leonardo

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Source: *Leonardo*, Vol. 19, No. 1 (1986), pp. 35-38
Published by: The MIT Press
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Solar-Powered Kinetic Sculpture: A Collaborative Educational Experiment

Andrew Stonyer, Ken Ford, Malcolm Hughes and Roger Linford

Abstract—This article describes the collaborative efforts of a group of artists and scientists to create kinetic sculptures responsive to changes in the heat or light of the sun. Kinetic responses were caused by density changes in liquids or expansion of wax-filled pistons exposed to the sun or by photocells controlling servo motors. Responses which ran counter to viewer expectation were frequently sought. Some issues arising from this collaboration are briefly discussed.

I. INTRODUCTION

Fluctuations in natural light have always enhanced the sense of life in sculpture; they modulate the surface appearance in a way that can bring conscious pleasure to a perceptive observer. In everyday life the forces that cause light to change can bring about real, as well as implied, movement. The same wind that moves clouds across the sun, obscuring light, can sway branches and young trees; the direct heat of the sun can make the landscape shimmer.

The work described in this paper began as part of an unusual research project involving close collaboration between artists and scientists [1]. Our topic was the application of solar energy to kinetic sculpture.

We wanted to explore methods by which sunlight could be harnessed to cause sculptures to move in interesting ways. In kinetic sculpture, actual movement—through its ability to depict changing relations—becomes a major aesthetic factor. Movement itself, rather than the method employed to produce it, is usually the main feature of interest [2–5]. In the work described in this article, however, we tried to create kinetic sculptures in which sunlight would be both cause and effect, used in such a way that the link between the two would become visually apparent.

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Manuscript solicited by John Holloway.
Received 5 July 1984.

II. EARLY STUDIES

Our starting point was Gabo's *Vibrating Wire*. In 1920, he constructed what was perhaps the first sculpture to be identified as kinetic—a thin wire that was made to oscillate rapidly in such a way as to create an apparent but illusory three-dimensional form. This form has been described as possessing "volume without mass".

Our approach, however, was different from Gabo's, as we wished to use solar energy to provide the motive power, and, if possible, in a way which would identify the sun as the driving force. We therefore examined different ways of using the sun's power, and we employed not only its light but also its heat.

To utilize the sun's heat, we constructed a maquette from a series of sealed glass tubes containing two immiscible layers of a three-component liquid mixture. Each layer was coloured with a dye, for easier observation. The mixtures were chosen to exhibit density inversion at a range of temperatures from 8° to 30°C [6]. The tubes were mounted on poles arranged in a rectangular configuration in such a way that only the less dense upper phase was visible. The tubes were then exposed to the sun. At various times of the day and at different seasons, the pattern of colour in the configuration of tubes would change due to density inversion of the liquid mixture in some of the tubes and the resulting color inversion.

Initially about 24 tubes were arranged in a square. The liquid mixture in the first tube was chosen so as to exhibit density inversion at 8°C, the next at 9°C and so on, so that as the day became warmer,

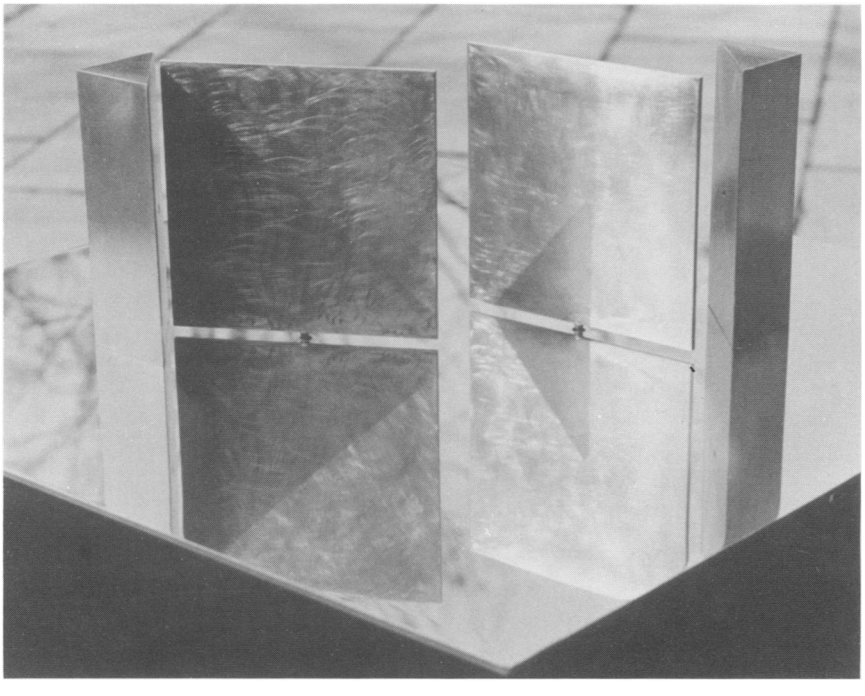

Fig. 1. Sculpture with two prisms and two revolving planes, stainless steel and mild steel, 75 × 75 cm. (Photo: Andrew Stonyer.)

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more tubes changed colour. This produced a rather obvious sequence of events, and we felt that it would stimulate the viewers' interest if pairs of tubes had their positions interchanged. We decided to interchange tubes on the basis of a non-random, but not initially obvious, sequence; for example, we would move the tubes in prime number positions (2, 3, 5, 7, 11, 13, etc.) to create various geometrical configurations.

In this, as in many of the later sculptures, we chose to provide a response that ran counter to viewers' anticipation. We wished the observer to notice the change taking place both in the sculpture and in the sunlight. In subsequent sculptures involving photocells triggering coloured lights, red was the response to winter. This is the reverse of the normal subjective expectation.

Early in our experimentation we also constructed some maquettes in which movement was powered by wax-filled pistons heated by the sun. For this we used devices similar to those used for the automatic opening of greenhouse windows. However, since the actual response of these maquettes to sunlight was slow and unproductive, we looked for ways to augment the response. One result of our experiments along these lines was a sculpture reminiscent of the aeolian harp. Vertical strings arranged in a cylindrical configuration were slowly and irregularly rotated past a static plectrum. Rotation was driven by a wax-filled piston exposed to sunlight. The visual shimmering of the strings was accompanied by gentle sounds which quite literally orchestrated changes in the sun's heat. Although this delicate sculpture was more effective than its predecessors in reacting to sunlight, we felt that still further reinforcement of the response was necessary.

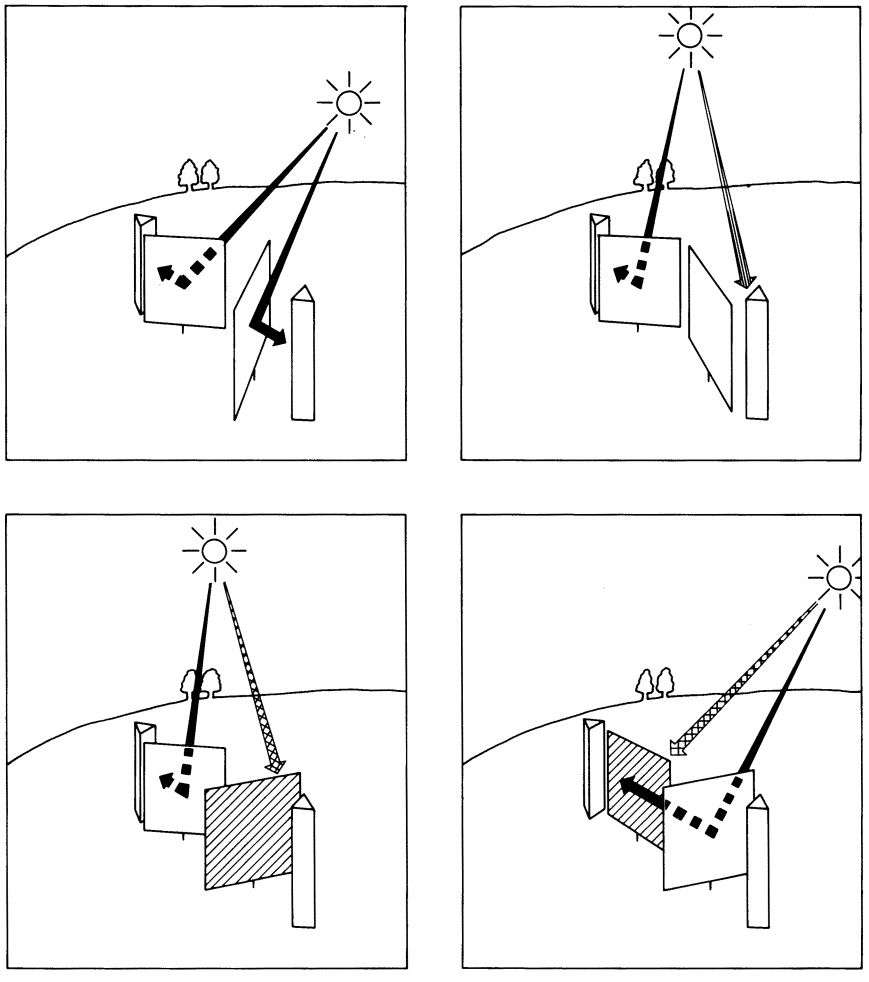

Fig. 2. The interaction of the two revolving planes with sunlight. Crosshatched arrows indicate light whose path to the photocell is obscured by the rotating plate. Striped arrow indicates light shining directly onto the photocell. Bold arrows indicate light reflected onto the photocell.

III. CENTRAL DEVELOPMENTS

We eventually decided to abandon direct response to solar heat as the cause of movement in our sculptures in order to explore the wider range of effects that could be produced by separating the response function from the motive power. We turned our focus to constructing comparatively large metallic surfaces subject to movements caused by photocell-powered servo motors.

In many of these works, reflective surfaces containing embedded photocells were placed in close juxtaposition. The amount of sunlight received by the photocell on one plate was affected by the relative position of a second plate, which acted as a mirror. The position of the mirror plate was controlled by the photocell toward which it reflected rather than by the photocell it contained. This gave rise to powerful feedback effects.

An initial effort involved using the two fundamental components of the sundial, the gnomen—the vertical element which casts the sun's shadow—and the dial plate—the surface upon which the shadow is cast. In this sculpture, fluctuations in the sun's visible light were translated into movement through the use of a photoelectric response. The reflective dial plate was penetrated at its centre by the vertical gnomen, the latter having a photocell mounted beneath an aperture in its top. The photocell output controlled an electric motor which caused the reflective plate to oscillate from side to side through an angle of 30°. Each 30 seconds of illumination was compared electronically with the previous 30 seconds, and the difference in the intensity of light between the two time segments caused a proportional rise or fall in movement. The sculpture was passive when the light remained constant. Consequently, a clear blue, or continually overcast, sky resulted in a marked absence of movement, whereas an irregular cloud cover caused intermittent movement. Generally, the stormier the sky, the more intense was the movement of the dial plate. Because the reflective surface of the dial plate enabled the motions of the sky to be seen in the actual sculpture, one was aware of the *cause* of kinetic movement. Concomitantly, since the movement of the dial registered the changes in these reflections, one was also aware of their *effect*. This gave rise to a sequence in which cause was continually juxtaposed with effect.

In the sculpture shown in Fig. 1, two triangular prisms are mounted on a stainless steel base in an east–west direction; between these prisms two square planes revolve clockwise or anticlockwise about their central axes. At the centre of the inside face of each prism is an aperture, behind which is a photocell positioned toward the adjacent square plane. Each photocell controls a servo motor in each base. The eastern plane is controlled by the western photocell and vice versa to destabilize and hence prolong the movement. Each plane

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rotates in a way that tends to maintain a constant level of illumination on the associated photocell.

As shown in Fig. 2, the planes position and reposition themselves so that the photocell apertures are either in shadow or penetrated directly by sunlight. If the illumination level is low, the planes attempt to position themselves to reflect additional light into the photocells. Thus the planes are both mirrors and deflectors. The base also reflects light and thus enhances and magnifies the movement of the planes. As with the previous sculpture, the reflective surfaces identify sunlight as the cause of movement, and changes in the quality of the reflected light are accompanied by their effect, i.e. the movement of one or both of the planes. In order further to intensify the movement of the planes, an irregular finish was applied to their surfaces. Because of the particular east–west orientation of this sculpture, the western plane moves during the morning and the eastern after midday. Consequently, kinetic movement is a response not only to sunlight but also to the sun's daily cycle.

We later extended kinetic movement in response to solar cycles to include a response to seasonal, as well as diurnal, cycles. In these later examples, the response mechanism was developed so that the speed, as well as degree of movement, depended on changes in sunlight. In one such small-scale sculpture, involving a response mechanism similar to the one described above, four triangular prisms define the north, south, east and west corners of a rectangle which encloses four revolving planes. Another related sculpture consisted of a rectangular prism surrounded by four revolving planes.

The idea behind these works was to demonstrate a symbiotic state through the relation between sun and sculpture. For instance, minor fluctuations in sunlight are accompanied by a few degrees of rotation, usually at a slow speed, while major fluctuations are accompanied by more extensive arcs of rotation. The kinetic movement reflects the daily and seasonal cycles of the sun, e.g. the north-facing plane becomes increasingly active during the early morning and late evening throughout the summer. The seasonal variations for each plane are displayed in Fig. 3.

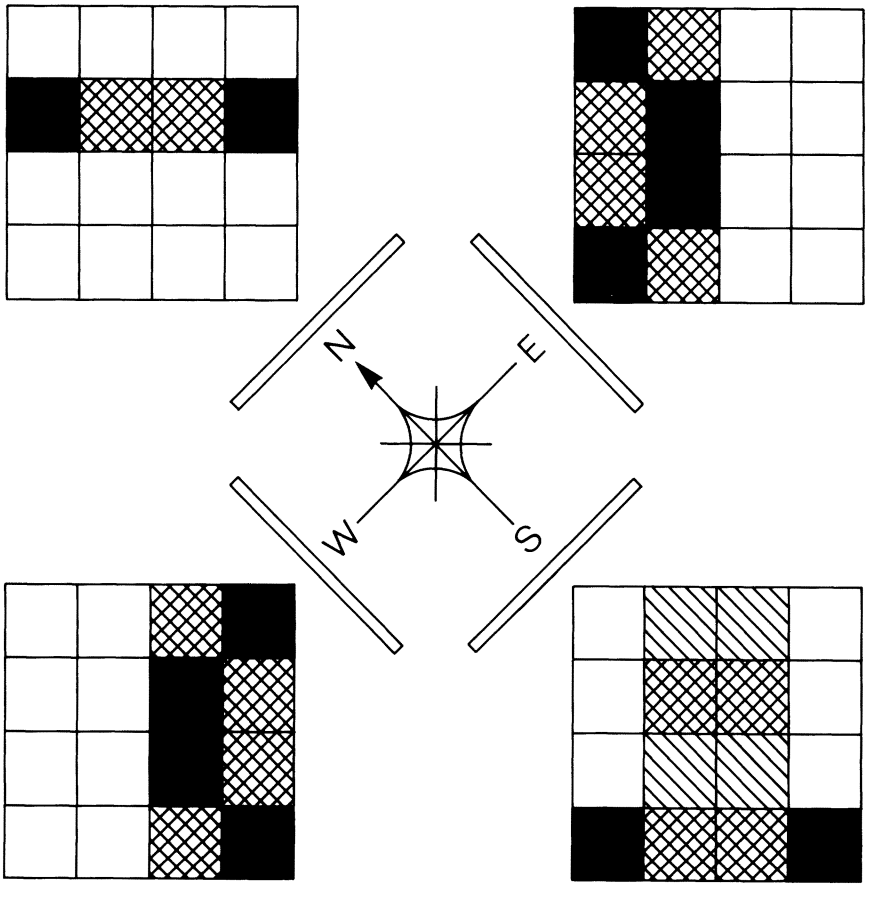

Fig. 3. Seasonal variation of movement for the sculptures with four revolving planes. The shading of individual squares indicates frequency of movement (white = still; shaded = intermittent; crosshatched = regular; black = extensive). The columns show daily variations in frequency of movement (left to right: sunrise, morning, afternoon, sunset). The seasonal variations are shown in the rows (top to bottom: spring, summer, autumn, winter). Thus the north plane's frequency of movement is 'still' (white square) at sunrise in the spring (upper left corner). The four planes are set out on the points of a compass as shown in the figure.

IV. SUBSEQUENT WORK

Since the completion of the research project, one full-size sculpture based on this work has been constructed [7]. This sculpture (Fig. 4 and Colour Plate **B, No. 3**) alters its geometry in response to the incident sunlight according to the time of the year, the time of day and the movement of the clouds. At the top of a column, two fixed and slightly inclined planes containing photocells are positioned. Two additional planes which pivot through 270° are positioned at the uppermost corners of these fixed planes. The rotating planes, driven by servo motors, attempt to position themselves to maintain a constant level of illumination on the associated photocells. As the illumination increases, the rotating planes close and move in such a way that they cast shadows across the face of the photocells. Alternatively, as the illumination decreases, the planes open out and search for light which they endeavour to reflect onto the photocells. This positive feedback can induce almost continuous movement. At around midwinter and at sunset, the planes are fully open in their search for sunlight. The association of closure with summer and openness with winter again involves a response contrasting with that normally associated with nature.

So far, this is the only photoelectrically powered sculpture that has been constructed to full scale. The other sculptures with rotating planes have been constructed only to 1/25 scale. If the opportunity arises for them to be built to full size, they could assume, in principle, a scale which would make them independent of an electrical power supply; thus, our original idea of entirely solar-powered kinetic sculpture might be realized. The planes perhaps could consist of panels of solar cells, and the energy stored in batteries housed in the prisms. The stainless steel base could be replaced by a pool of water. The patterns of rippling water resulting from the movement of the planes could suggest the desired symbiotic relationship between the sculpture and sunlight.

V. ASPECTS OF COLLABORATION

As a generalization, the problems we encountered in this experimental collaboration between artists and scientists were in the areas that we anticipated (such as communication) but of a nature that

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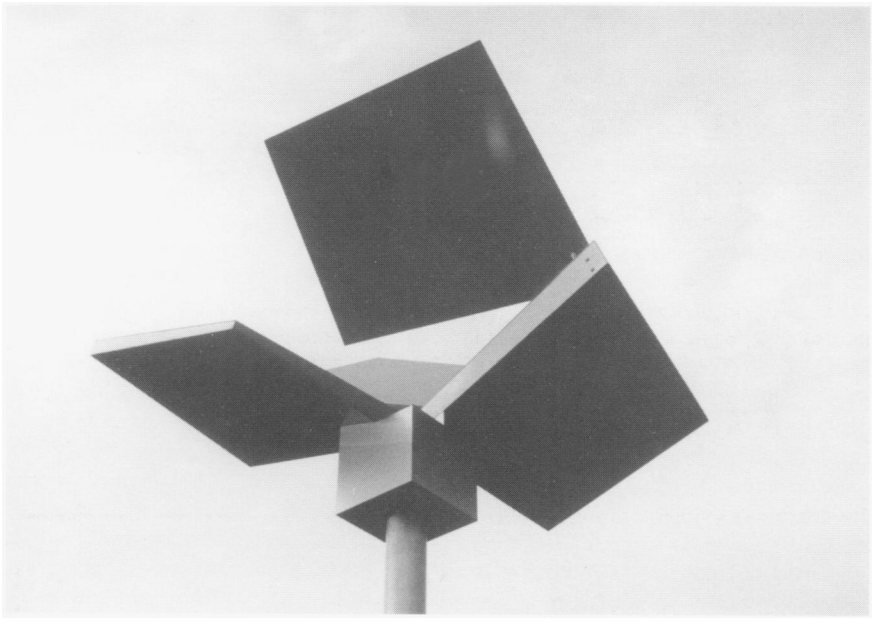

Fig. 4. ***Crown Court Square, Leicester, Sculpture*****, anodized aluminium, 5 m high. (Photo: Andrew Stonyer.) This sculpture alters its geometry in response to the incident sunlight according to the time of year, the time of day and the movement of the clouds.**

often surprised us. The differences in approach, philosophy and methodology between the two disciplines caused few difficulties. Semantics and word usage, however, were awkward at times. Some of our early ideas were too allied to their parent discipline and thus artificial in the sense that they involved constructing maquettes more suited to scientific experimentation than to serving an artistic purpose or they necessitated needlessly complicated scientific or technological solutions to over-rigid artistic specifications. These preliminary ideas, however, provided us with the opportunity to develop leitmotifs, such as the use of contrasting rather than anticipated responses.

The ultimate benefits of working closely together for several years were that both artists and scientists came to understand that their working methods are surprisingly similar; that both pursue goals of enquiry in a determined and creative fashion; and that, once acquired, the skill of communicating with practitioners of a foreign craft need never be forgotten.

Acknowledgements—The authors wish to acknowledge educator Albert Pountney, who led the vigorous debate on the feasibility of carrying out formalized research in the fine arts which laid the groundwork for this project. We also wish to thank chemist David Armitage and physicist Hugh Jones for their substantial contributions to this work.

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3. P.K. Hoenich, "Kinetic Art with Sunlight: Reflections on Development in Art Needed Today", *Leonardo* **1,** 113 (1968).
4. P.K. Hoenich, "Light Symphony No. 1: Kinetic Pictoral Artwork with Light", *Leonardo* **14,** 38 (1981).
5. J. van Santen, "Light Modules: Pictoral Artworks Produced by Daylight Projected onto a Translucent Screen", *Leonardo* **14,** 134 (1981).
6. The actual system we employed was a mixture of three liquids (normal octane, methyl alcohol and carbon tetrachloride), which separates into two layers or phases. The carbon tetrachloride is very much denser than the other two components and, as the temperature rises, more of it dissolves in the upper layer. At a certain temperature, which can be selected by carefully choosing the relative amounts of the liquids sealed into the tube, the upper layer becomes denser than the lower and consequently sinks to the bottom of the tube, so that the two layers interchange positions.
7. The sculpture was constructed for the Crown Court at Leicester, U.K.

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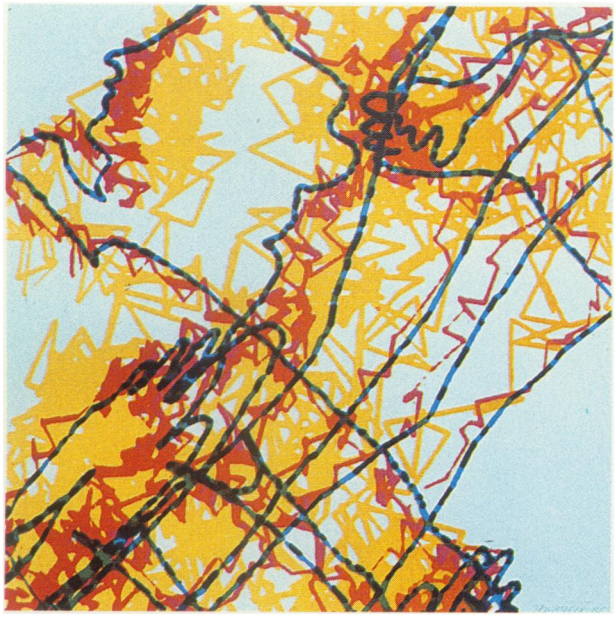

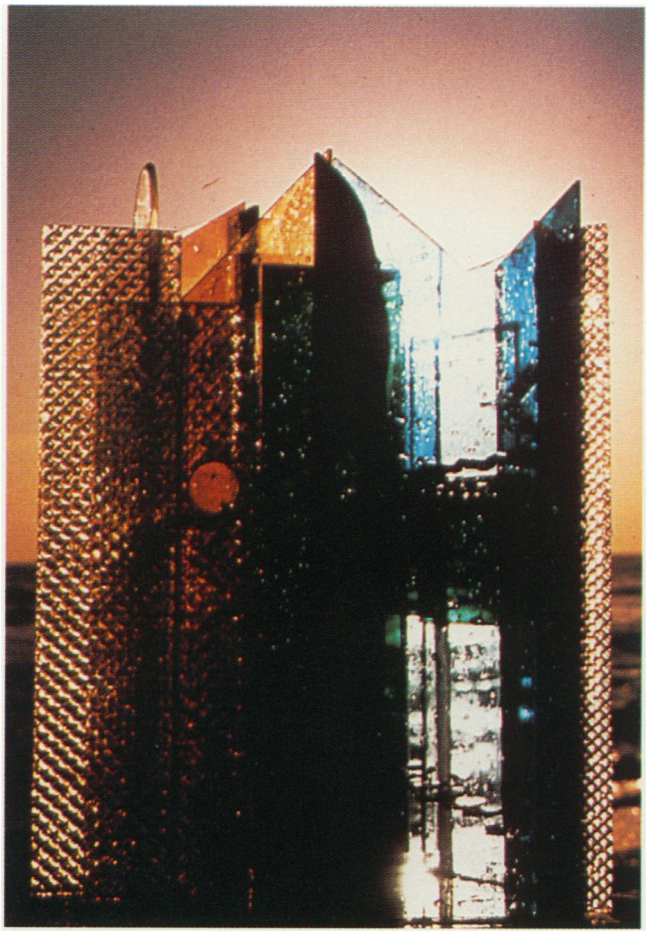

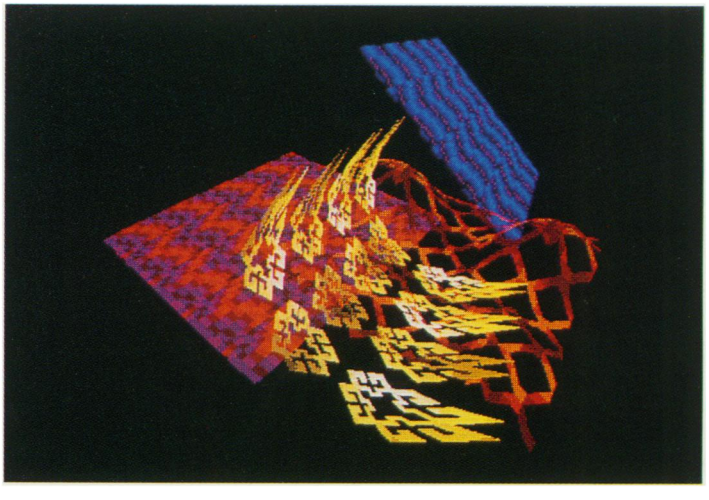

Plate B

No. 1. Top left. Imrich Bertók. *The Squash No. 2,* computer graphics — serigraph, yellow, brown, blue and red, 64 × 64 cm, 1984.

No. 2. Top right. Alex Maller. *Castle in the Sea* by Oded Peperman, colored plastics, plexiglass, glass, steel rods, the sea, natural sunlight, 60 × 60 × 120 cm, scale 1:100.

No. 3. Bottom left. Andrew Stonyer *et al. Crown Court Square, Leicester, Sculpture,* anodized aluminium, 5 m high.

No. 4. Bottom right. Theo Goldberg. An image from the multimedia show *Sheherezade,* 35 mm slide, 1985.

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